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Investigation of electromagnetic radiation of the control channel of a small-sized unmanned aerial vehicle for attenuation

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Abstract. An urgent problem of our time is to counteract the illegal use of civilian unmanned aerial vehicles (quadrocopter type). The problem of detecting quadrocopters is related to their low visibility, including in the electromagnetic wavelength range. As a result, it is relevant and appropriate to develop a budget device for countering such aircraft. At the initial stage to achieve this goal, we studied the General principles of control of the civil quadrocopter "Xiaomi Mi Drone 4k", determined its most significant unmasking feature (electromagnetic radiation of the control channel), measured the electrical component of the electromagnetic field from its control panel in order to further calculate the signal attenuation coefficient for detecting the operator of an unmanned aerial vehicle.

1. Introduction

Unmanned aerial vehicle (UAV) is an aircraft that excludes the presence of the pilot inside, having the ability to control "from the ground " by the operator, autonomously or automatically according to preset coordinates, or a hybrid method with the ability to adjust the course, fly over obstacles using the control panel.

Illegal use of UAVs creates the following threats:

- opening an organization for the protection and defense of sensitive facilities;
- collection of information about the daily activities of the object, its belongings and tasks to be solved, the deployment of forces and means at the object, technical and transport means used;
- intelligence of radio-electronic means and transmitted messages (identification of cell phone numbers and identifiers of radio-electronic means located at the facility, determination of their location, obtaining semantic data, hacking of Wi-Fi access points);
- disorganization of the control system (when using interference as transmitters);
- committing a terrorist act.

UAVs can be used to implement technical channels for information leakage, such as: species, transient electromagnetic pulse emanation standard (TEMPEST), chemical, television, infrared, and radiation.

By designation, UAVs are divided into civil and military. Our research focuses on civilian UAVs, as they are budget-friendly, popular, and publicly available, and as a result, are actively used for illegal purposes.



Common models of civilian UAVs consist of a flight controller with various sensors depending on the configuration and manufacturer: an accelerometer, a gyroscope, a geo-positioning sensor, a camera, a video transmitter, a video receiver, a display (in many models, the display is a mobile phone) and a radio control panel. The diagram of interaction of the control panel with the UAV is shown in figure 1 [1].

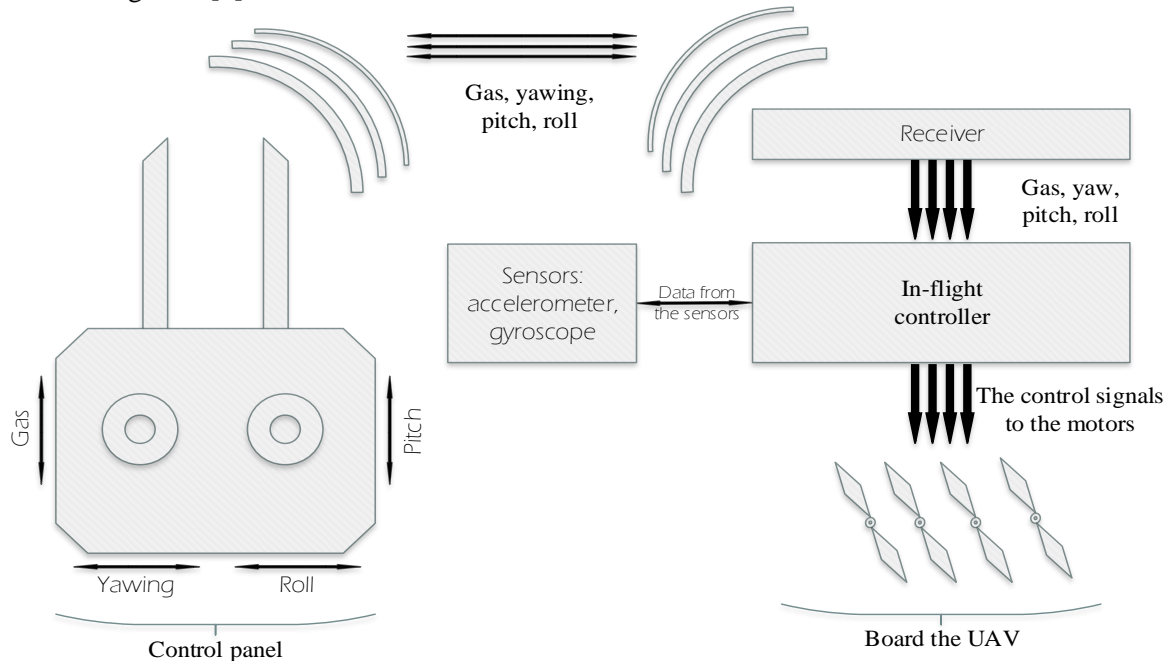


Figure 1. General scheme of interaction of the control panel with a civilian UAV.

Operating frequency ranges of civilian UAVs [2]:
 433MHz (433.05 – 434.79 MHz) – control;
 868 MHz (863 – 870 MHz) – control;
 900 MHz (902 – 928 MHz) – video transmission;
 1.2 – 1.3 GHz – video transmission;
 Beidou (1.20714 GHz / 1.26852 GHz / 1.5750 GHz) – geolocation;
 GPS (1.17645 GHz / 1.2276 GHz / 1.5754 GHz) – geolocation;
 GLONASS (1.202025 GHz / 1.246 GHz / 1.602 GHz) – geolocation;
 Wi-Fi: 2.3 GHz (2,300 – 2,550 GHz) and 5.8 GHz (5,725 – 5,875 GHz) – video management and transmission.

An example of the frequency and transmission range of the control signal of popular civil UAVs from DJI (China) is presented in table 1 [3].

Table 1. The frequency range and the range of popular models of civil UAVs.

№ p/p	UAV model	Radio frequency, MHz	The signal transmission distance
1.	DJI Phantom 3 Professional	2400 – 2483	In open areas up to 5 km
2.	DJI Phantom 3 Standart	5725 – 5825	In open areas up to 1200 m
3.	DJI Phantom 4 Professional	2400 – 2483	In open areas up to 7 km

Currently, despite certain attempts by the legislator to regulate certain aspects of the use of UAV, the Russian legal framework in this area is not yet sufficiently developed and requires significant changes, primarily of legal and organizational nature [4].

Thus, in accordance with paragraph 3.2 of article 33 of the Air code of the Russian Federation you need to register unmanned civil aircraft with a maximum takeoff weight from 0,25 kilograms to 30 kilograms imported to Russia or manufactured in Russia in the manner established by the Government of the Russian Federation [5]. It should be noted that the Rules came into force only on September 27, 2019, [6] for this offense, a minor administrative fine (2500 rubles) is provided. These circumstances, as well as the intent of illegal use of UAVs, contribute to ignoring the established rules. It should be noted that according to the roadmap of one of the directions of the scientific and technological initiative of the Russian Federation -AeroNet (creation of distributed unmanned aircraft systems), by 2035, no less than 100 thousand unmanned aircraft will be permanently in the air over the territory of Russia, combined into a single system of providing works and services to meet various, constantly increasing needs of the economy [7]. Thus, protecting the interests of citizens and organizations from the illegal use of UAVs is an urgent problem of our time.

One of the ways to counteract civilian UAVs is to monitor a certain range of frequencies on air, intercept and analyze control packets in order to extract the coordinates of the UAV operator. Modern technologies allow not only to interrupt the control of the UAV (directional noise generator) or intercept it, but also to calculate the location of the operator.

Unmasking signs of UAVs are: species, electromagnetic radiation and acoustic noise from propellers/engines (not relevant to silent quadrocopters).

The problem of detecting UAVs was investigated by the authors [8, 9], and there are also patents for inventions [10, 11]. The authors studied electromagnetic signals that are modulated by the rotation frequency of the engine's rotor (crankshaft). Patents for inventions describe complex UAV detection systems based on radio frequency and acoustic sensors, as well as optical systems. The disadvantages of such systems are the complexity of execution and significant financial costs for their implementation. Our proposed solution is aimed at developing a budget device for countering such UAVs with the required efficiency.

2. Methods and materials

To develop budget means of detection and counteraction, the UAV control channel with the operator's control panel was investigated for signal attenuation in order to determine the distance of possible detection of an informative signal from the UAV under study. We used a relatively cheap quadrocopter "Xiaomi Mi Drone 4k", with a camera and a separate remote control in the form of a joystick over a Wi-Fi radio channel with a frequency of 5 GHz.

The study consisted in measuring the electrical component of the electromagnetic field of the UAV control channel using the software and hardware complex for searching and measuring side electromagnetic radiation and cues "Navigator-P5M" as in a room with a real situation on air, and in the anechoic chamber Rainford EMC3 (from the equipment of the "Center for collective use of the Federal State Autonomous Educational Institution of Higher Education Ural Federal University named after the first President of Russia B.N. Yeltsin"). Indoor flight mode – no sensors geolocation. The composition of the software and hardware complex "Navigator-P5M" for measurements is shown in table 2.

Table 2. Composition of the hardware and software complex.

Name of measuring instruments	Type	Factory number	Frequency range, MHz
Complex for measuring parameters of side electromagnetic radiation and interference	Navigator-P5M	170005	-
Spectrum analyzer	FSV 13	101677	0,009-12000

Table 2. Composition of the hardware and software complex.

Name of measuring instruments	Type	Factory number	Frequency range, MHz
Antenna log-periodic aerial	LPA-2	17015	1000-12000

Test signals were used to start/stop UAV engines.

Measurements were made relative to 1 mV/m in the bandwidth of the 100 kHz measuring receiver for the range from 1000 MHz to 12000 MHz.

3. Research results

The highest level of intensity of the electric component of the electromagnetic field from the control panel of the UAV under study when the engines are running is observed in the frequency range from 5729 MHz to 5782 MHz (figure 2).

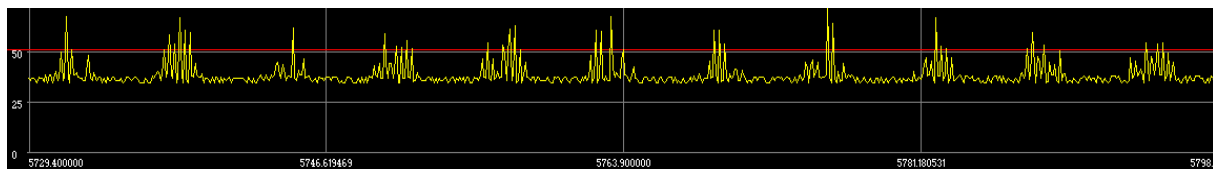


Figure 2. Values of intensity levels of the electric component of the electromagnetic field from the UAV control panel.

Measurements of the attenuation of the electrical component of the electromagnetic field of the signal from the control panel of the UAV with running engines were carried out at a distance of 1 m and 7 m (the maximum possible distance in the anechoic chamber). The results of the research are presented in table 3.

Table 3. The result of measuring the electrical component of the electromagnetic field of the signal from the UAV control panel.

No p/p	f_{CI} , MHz	E_1 , dB	E_2 , dB
1.	5761.30	101.63	88.60
2.	5761.90	102.48	90.08
3.	5763.90	103.50	89.80
4.	5767.60	101.65	82.60
5.	5771.90	63.32	49.49
6.	5772.90	59.12	50.36

Symbols used in table 3:

f_{CI} – measured frequencies of test signal components;

E_1 – measured levels of the electric component of the UAV radiation field at 1 m;

E_2 – measured levels of the electric component of the UAV radiation field at 7 m.

Thus, the obtained measurement results at 1 and 7 meters give an idea of the signal attenuation and are the basis for calculating the real attenuation coefficient and the prospects for further research and development of UAV countermeasures.

4. Conclusion

During the study, using the example of the UAV model "Xiaomi Mi Drone 4k", one of the unmasking features of the UAV was studied – electromagnetic radiation from the control panel, which can be used to detect the UAV operator. The obtained values of the intensity of the electrical component of the electromagnetic signal at different distances allow us to calculate the attenuation coefficient, using which it is possible to calculate the signal strength from the object under study at any desired distance.

It should be noted that in real conditions, the attenuation coefficient will differ from that measured in an anechoic chamber, since the propagation of an electromagnetic signal depends on many factors (electromagnetic environment in the air (industrial noise), the presence of obstacles in the path of propagation, including metal ones, etc.). Therefore, in urban conditions, it is impossible to calculate the universal attenuation coefficient.

Measurements also showed that the UAV under study without a connected camera is only a receiving antenna for commands from the control panel, which is the source of an informative signal.

The purpose of our further work is to justify and develop the cheapest and most effective means of detecting UAVs. It is planned to conduct a series of studies of network packets transmitted from the control unit to the UAV, from the UAV camera using the remote at the phone's display, and also the acoustic spectrum from the engines of the UAV with the use of a security evaluation system, acoustic speech information.

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